MODELLING AND FORECASTING MORTALITY RATE DUE TO MALARIA INFECTION, USING AUTOREGRESSIVE MOVING AVERAGE (ARMA) MODELS

A PANACEA TO NIGERIAN SOCIO-ECONOMIC CHALLENGES

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ABSTRACT

This research work was based on fitting Autoregressive moving average (ARMA) model and the forecasting of Mortality rate due to Malaria infections in Nigeria, using the medical records of General Hospital Ifo, Ogun state between January 2009 to December 2015, with the aim of recommending adequate checks in possible malaria escalation around the globe. Based on the plotted Autocorrelation functions (ACF) graph of the original series and the Augmented Dickey Fuller (ADF) test carried out, it was observed that the series was non-stationary which necessitated the series to be differenced to attain stationarity. This stationary series data was modelled in order to determine the stability of the parameters estimation. The plots of the ordinary and differenced series autocorrelation and partial autocorrelation functions suggested some models for selection but the Akaike and Bayesian Information Criterion was used to select the model that really provided the best fit for the series. ARMA (1,1) was found to be best fitted model as a result of their lower AIC and BIC values, and this was used for future forecast. The result shows that the distribution of forecast

tend to follow a downward trend with ± 2 *standard error limit. Therefore, there is high tendency for mortality rate due to malaria infection to reduce drastically between the forecasted periods of 2016 – 2018.*

Keyword: Malaria, Autocorrelation Function, Partial autocorrelation Function, Stationary, Bera-Jarque.

INTRODUCTION

Malaria is a mosquito borne disease caused by a parasite called plasmodium. This plasmodium has four species which include plasmodium falciparum, plasmodium vivax, and plasmodium ovale and plasmodium malariae. Malaria parasite is transmitted from one person to another through the bite of a female Anopheles Mosquito which require blood to nurture her eggs. When Malaria parasites enter the blood stream of a person, they infect and destroy the red blood cells. The destruction of these essential cells leads to fever and flu-like symptoms such as chills, headache, muscle aches, tiredness, nausea, vomiting and diarrhoea.

Malaria, when not treated, can lead to coma and hence death. Globally, Malaria is increasingly becoming a disease of serious concern to everybody. This is because day by day, the impact of Malaria in human existence, the world over, becomes more ravaging and damaging as a result of high morbidity and mortality experienced in different parts of the globe especially the developing countries of which Nigeria is one. The first recorded treatment of Malaria dates back to 1600, when the bitter bark of cinchona tree in peru was used by the native Indians. Not until 1889 was the protozoa (single celled parasite) cause of Malaria discovered by Alphonse Laveran and only in 1987 was the Anopheles Mosquito demonstrated to be the vector for the disease by Ronald Ross. The discovery of Ronald Ross

was followed by a series of important works which not only enlarged the understanding of Malaria but also supplied useful knowledge in the combat against Malaria and prevention of Malaria. Despite initial success, there was a complete failure to eradicate Malaria in many countries (Mills et al; 2008). According to World Health Organization (WHO), Centre for Disease Control and Prevention (CDCP), Roll Back Malaria Partnership (RBM) (2010), 3.3 billion people-half the world's population- are at risk of Malaria; one million people die each year from Malaria; every 30 seconds a child dies from Malaria. Malaria is responsible for over 10% of the overall African disease burden. Children under five years of age (22% of the population) and pregnant women (20% of the population) are the most vulnerable to Malaria disease (Guillet et al, 2001). In 2015, approximately 3.2 billion people – nearly half of the world's population – were at risk of malaria. According to the latest WHO estimates, released in December 2015, there were 214 million cases of malaria in 2015 and 438000 deaths. Between 2000 and 2015, malaria incidence among populations at risk fell by 37% globally; during the same period, malaria mortality rates among populations at risk decreased by 60%. An estimated 6.2 million malaria deaths have been averted globally since 2001. Sub-Saharan Africa continues to carry a disproportionately high share of the global malaria burden. In 2015, the region was home to 88% of malaria cases and 90% of malaria deaths. Some 15 countries – mainly in sub-Saharan Africa – account for 80% of malaria cases and 78% deaths globally.

This study is aimed at fitting an ARMA Model for mortality cases due to malaria infection and employ the model in forecasting future mortality rates caused by Malaria. And hence, offer suggestions on how to maintain steady decrease of deaths attributed to Malaria infections.

LITERATURE REVIEW

Many researches have been done in the past regarding incidence and mortality in Malaria. Durueke (2005) carried out a research on the incidence, management and bionomic of malaria in children under 5years of age in parts of Isiala Mbano L.G.A, Imo State, from November 2004 to August 2005 using a chi-square test for proportion, the result revealed that the incidence of malaria in the studied area was inversely proportional to the socio-economic levels of the areas under study. Also, the incidence of malaria increased with decrease in socioeconomic level and decreased with improvement in standard of living. Gerritsen et al (2008) carried out an analysis on malaria incidence in Limpopo Province South Africa from 1998 to 2007, using chi-square test of independence and time series analysis, the result showed that out of 58768 cases of malaria reported including 628 deaths, the mean incidence of malaria was 124.5 per 100, 000 person and the mean mortality rate was 1.1% per season. Also, there was a decreasing trend in the incidence over time, and the mean incidence in males was higher than in females. Finally, the result revealed that incidence in malaria peaked at the age of 35 to 39 years, decreased with age from 40 years and is lowest in 0 – 4years old. The Cohort Fertility Rate (CFR) increased with increasing age. Ayeni (2011) conducted a research on Malaria Morbidity in Akure South West, Nigeria using time series analysis. The result revealed that malaria morbidity was generally low before 2004 and that the reported cases of malaria increased from 43, 533 in 2004 to about 62, 121 cases in 2008. From the result also, malaria morbidity index revealed an increase of 0.005 annually between 2000 and 2008. Korenromp et.al (2007) carried out a study titled "Forecasting Malaria Incidence based on monthly case reports and Environmental Factors in karuzi Burudi, from 1997 to 2003". Using time series analysis, the result revealed that the exploration of the incidence of malaria, precipitation, temperature

and vegetation for 1997 to 2003 showed no clear trend, and suggests a seasonal dependency in the series with a 6-month period for the incidence and a 12-month period for rainfall, temperature and vegetation. Opara (2001) carried out a study titled “The effects of malaria during pregnancy on infant mortality in Abia State Nigeria between 1993 and 1999”. Using chi-square test for independence, the result showed that malaria during pregnancy increased neonatal mortality by lowering birth weight. Adebola and Okereke (2007) conducted a study titled “Increasing Burden of Childhood Severe Malaria in a Nigerian Tertiary Hospital: Implication for control, between January 2000 and December 2005”. Using logistic Regression, the result showed that severe Malaria constituted an important cause of hospital admission among Nigerian children especially those aged below 5years. The result also revealed that there was significant increase in the proportion of cases of severe malaria from 2000 to 2005. Baird, et al (2002) conducted a research on the seasonal malaria attack rates in infants and young children in northern Ghana from 1996 to 1997. Using fisher’s exact test and chi-square test of independence, the result showed that the mean parasitemia count at the time of reinfection in the dry season roughly equaled that in the wet season.

METHODOLOGY

The data for this study was obtained mainly from secondary data. The source of the data is General Hospital Ifo, Ogun State, Nigeria for periods of eighty four (84) months between January 2009 to December 2015.

The analytical technique employed is Autoregressive moving average (ARMA). This model and its associated features of Stationarity, differencing, ACF, PACF and forecasts were analyzed using E-view package.

- **STATIONARITY**

The theory behind ARMA estimation is based on stationary time series. A series is said to be (weakly or covariance) stationary If the mean and auto-covariance of the series do not depend on time.

Let {Xt} be a time series with $E(X^2t) < \infty$.

The mean function of {Xt} is $\mu_x^{(t)} = E(X_t)$. (1)

The covariance function of {Xt} is

$$Yx(r,s) = cov\ (Xr\ Xs) = E\big[Xr - \mu x(r)\big)(Xs - \mu x(s))] \quad (2)$$

For all integers r and s, {Xt} is (weakly) stationary if;

I. $\mu x\ (t)$ is independent of t, and;

II. $Yx(t+h,t)$ Is independent of t for each h.

Strict stationary of a time series $\{X_t, t = 0, \pm 1,\}$ is defined by the condition that $\big(X_{1,\ldots\ldots\ldots\ldots} X_n\big)\ and\ \big(X_{1+h,}\ \ldots\ldots\ldots\ldots, X_{n+h}\big)$have the same joint distributions for all integers h and n > 0. Brockwell and Davis, (2012).

- **THE ARMA PROCESS**

A time series $\{X_t\}$ is said to follow an autoregressive moving average model of order $p.q\ \{ARMA(p,q)\}$ if it satisfies

$$X_t - \emptyset_1 X_{t-1} - \cdots - \emptyset_p X_{t-p} = \in_t - \ \theta_1\ \in_{t-1} - \cdots - \theta_q\ \in_{t-q} \quad (3)$$

By multiplying (3) with X_{t-k} and take expectation of both sides, we have

$$E(X_tX_{t-k}) - \emptyset_1 E(X_{t-1}X_{t-k}) - \cdots - \emptyset_p E(X_{t-p}X_{t-k}) = E(\in_t X_{t-k}) - \theta_1 E(\in_{t-1} X_{t-k}) - \cdots - \theta_1 E(\in_{t-q} X_{t-k}) \quad (4)$$

Where $E(X_tX_{t-k})$ and $E(\in_t X_{t-k})$ are auto covariance and cross auto covariance respectively.

RESULTS AND DISCUSSION

Results

Stationarity Check and Determination of the Appropriate Arma Order

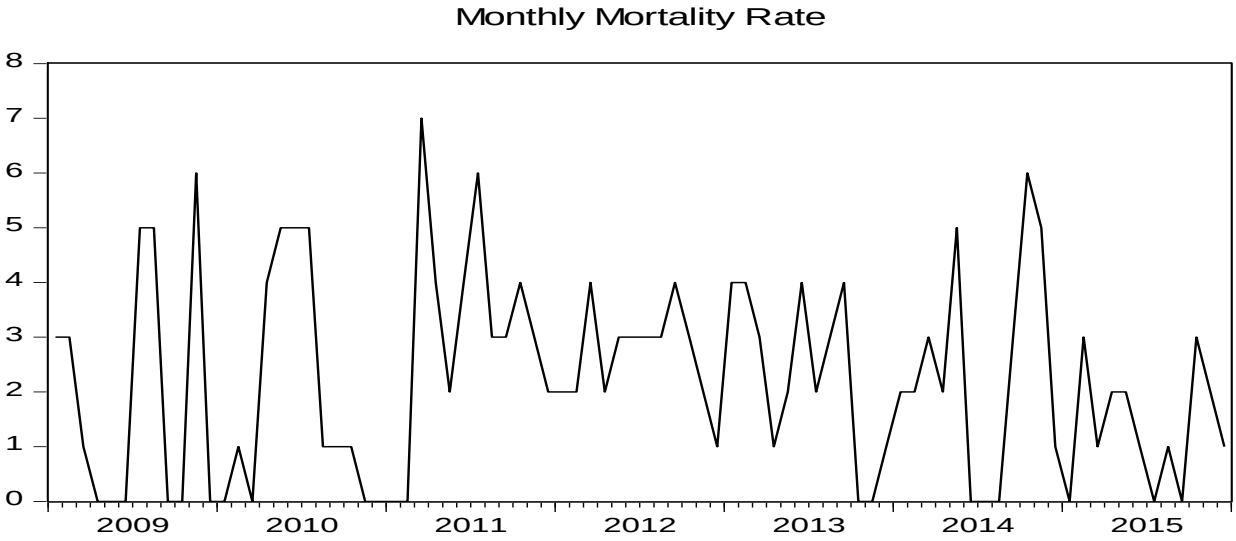


Fig 1: Time Plot of General Hospital Ifo Mortality Rate due to Malaria Infection

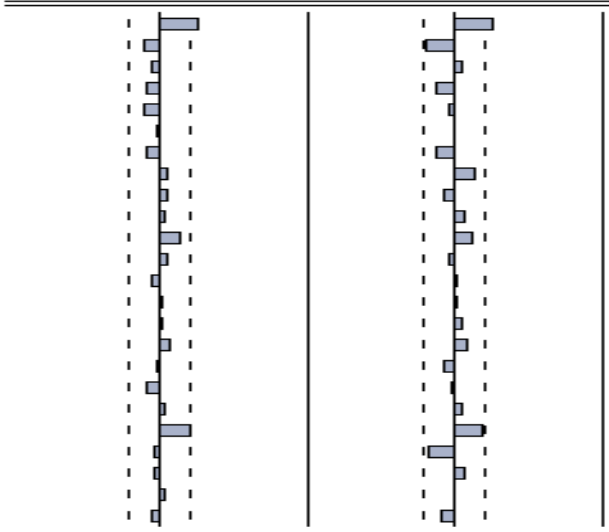
Table 1: Augmented Dickey-Fuller Test for Series Stationarity

Dickey-Fuller test statistic	Lag order	P-value
-6.741674	11	0.0000

Significant at 1%, 5% and 10% level

Correlogram of MONTHLY_MORTALITY_RATE

Date: 08/05/16 Time: 22:26
Sample: 2009M01 2015M12
Included observations: 84



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.278	0.278	6.7122	0.010
		2	-0.111	-0.204	7.8027	0.020
		3	-0.051	0.049	8.0321	0.045
		4	-0.087	-0.122	8.7106	0.069
		5	-0.100	-0.044	9.6308	0.086
		6	-0.018	-0.000	9.6619	0.140
		7	-0.095	-0.135	10.516	0.161
		8	0.046	0.131	10.721	0.218
		9	0.048	-0.072	10.943	0.280
		10	0.034	0.073	11.059	0.353
		11	0.146	0.121	13.165	0.283
		12	0.056	-0.043	13.483	0.335
		13	-0.050	0.022	13.740	0.392
		14	0.019	0.024	13.778	0.466
		15	0.024	0.046	13.840	0.538
		16	0.066	0.095	14.305	0.576
		17	-0.012	-0.079	14.320	0.644
		18	-0.097	-0.011	15.349	0.638
		19	0.025	0.057	15.420	0.696
		20	0.213	0.192	20.526	0.425
		21	-0.039	-0.173	20.697	0.478
		22	-0.042	0.073	20.907	0.526
		23	0.031	0.004	21.018	0.580
		24	-0.064	-0.083	21.517	0.608

Figure 2 ACF And PACF Plots of Mortality Rate Due To Malaria Infection

Table 2: ARMA (1,1) Model For Mortality Rate Due to Malaria Infection

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AR(1)	0.997590	0.004488	222.2788	0.0000
MA(1)	-0.979627	0.021337	-45.91251	0.0000
R-squared	-0.012040	Mean dependent var		2.240964
Adjusted R-squared	-0.024534	S.D. dependent var		1.845167
S.E. of regression	1.867665	Akaike info criterion		4.111057
Sum squared resid	282.5420	Schwarz criterion		4.169342
Log likelihood	-168.6088	Hannan-Quinn criter.		4.134472
Durbin-Watson stat	1.448378			
Inverted AR Roots	1.00			

The model specification of table 2 is written as:

$$Y_t = \phi_1 Y_{t-1} + \theta_1 \varepsilon_{t-1} + \varepsilon_t \qquad (5)$$

Where ϕ_1 and θ_1=are Coefficients of AR(1) and MA(1) respectively. ε_t is the error term. Substituting the coefficients, we have;

$$Y_t = 0.99759Y_{t-1} - 0.979627\varepsilon_{t-1} \quad (6)$$

DIAGNOSTIC CHECK ON ARMA (1,1)

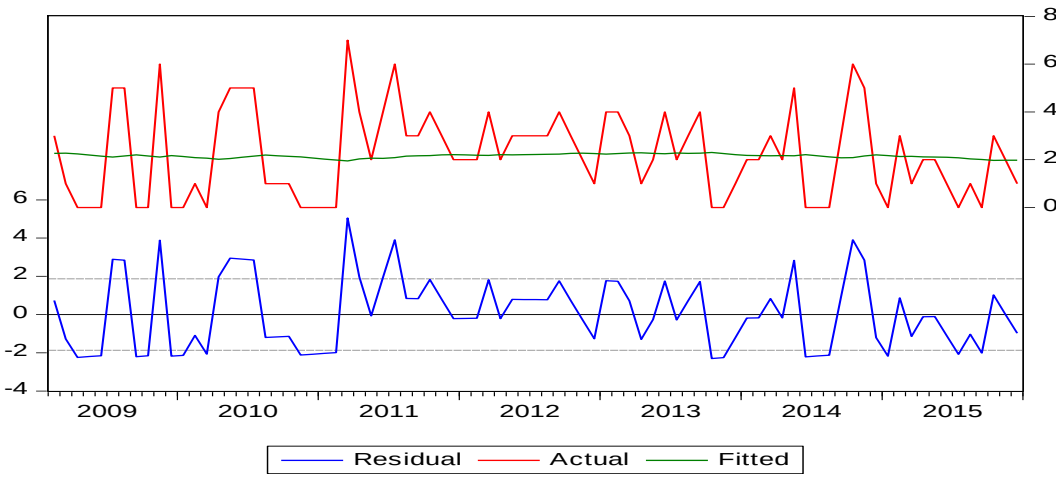


Fig3: Plot of Residual, Actual and Fitted Values of Mortality Rate using ARMA(1, 1)

Correlogram of Residuals

Date: 08/06/16 Time: 20:53
Sample: 2009M02 2015M12
Included observations: 83
Q-statistic probabilities adjusted for 2 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.272	0.272	6.3434	
		2	-0.116	-0.205	7.5168	
		3	-0.053	0.045	7.7681	0.061
		4	-0.089	-0.123	8.4709	0.067
		5	-0.102	-0.048	9.4170	0.069
		6	-0.030	-0.015	9.5009	0.072
		7	-0.106	-0.139	10.546	0.081
		8	0.050	0.132	10.784	0.095
		9	0.051	-0.073	11.034	0.137
		10	0.024	0.058	11.088	0.197
		11	0.151	0.134	13.330	0.148
		12	0.062	-0.046	13.709	0.187
		13	-0.048	0.026	13.940	0.236
		14	0.022	0.027	13.991	0.301
		15	0.015	0.034	14.013	0.373
		16	0.055	0.096	14.327	0.426
		17	-0.021	-0.089	14.375	0.497
		18	-0.104	-0.007	15.560	0.484
		19	0.031	0.060	15.668	0.547
		20	0.218	0.189	21.012	0.279
		21	-0.035	-0.159	21.155	0.328
		22	-0.038	0.066	21.319	0.379
		23	0.036	0.015	21.469	0.431
		24	-0.061	-0.085	21.910	0.465

Figure 4: Correlogram of Residuals for ARMA (1, 1) model

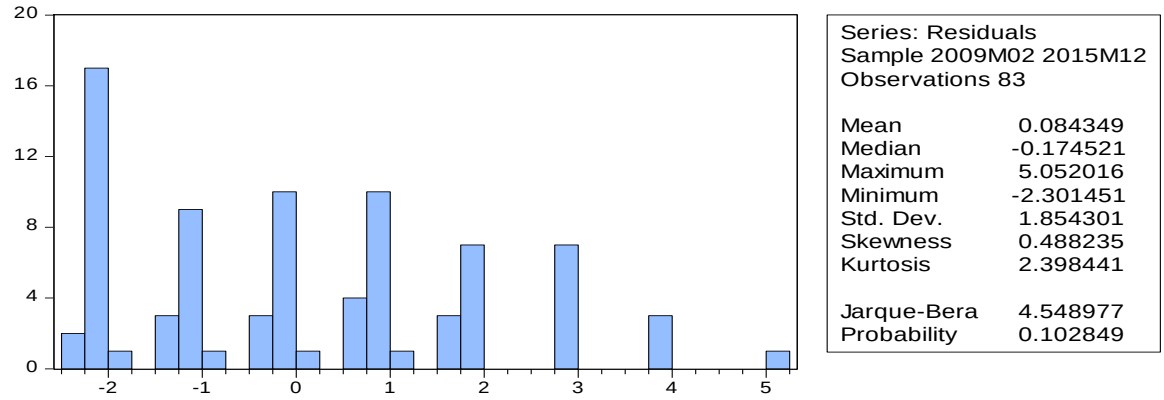


Figure 5 Histogram And Normality Test Of Residuals using Bera-Jarque test

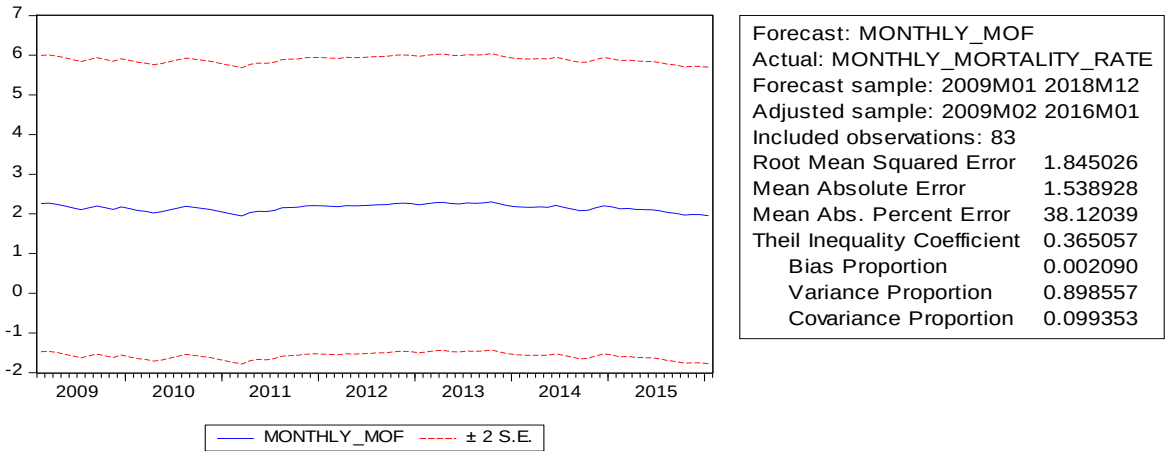


Figure 6: Forecast plot of Deaths due to Malaria Infection

DISCUSSION

Figure 1 above indicates the time plot which shows that the series is not stationary. The correlogram plot in fig. 2 indicates significant spikes at the first lag and a downward trend from lag to lag where the tail of the ACF and PACF cut off at zero.

Confirmatory analysis on the stationary test was adopted using ADF test. The null hypothesis (H_0) in the test signifies that the time series data is non-stationary while alternative hypothesis (H_1) is that the series is stationary. The hypothesis then is tested by performing appropriate "level" order of differencing and applying the ADF test to the time series data. The ADF test result, as obtained upon application as shown in table 1 gives a test statistic of -6.741674 with maximum lag order 11 and P-value of 0.0000. From this result, we therefore fail to accept the null hypothesis and hence concludes that the series is stationary in its mean and variance.

This test makes it possible to advance to the fitting of ARMA model. Decision was made on reasonable values of the orders of the Autoregressive (AR(ϕ) and Moving Average (MA(θ)), since the series were not found to be seasonal in nature. However, the correlogram of the series AR (1) and MA (1) gives the best model because of the significant spikes in order 1 for the PACF and ACF plot and both also tail off at zero, which necessitates ARMA (1,1).

Table 2 shows an [AR(1)] with coefficient of 0.99759, a student t-statistic of 222.279 and a p-value of 0.000 including a Moving Average[MA(1)] of -0.979627, t-statistic of -45.9125 with P-value of 0.000. This indicates that both MA and AR terms were found to be statistically significant since the P-value is less than the 0.05 level of significance. The AIC of 4.11106, log likelihood of -168.6088, and BIC of 4.16934 attest to the validity of this fitted model. Fig 3 indicates that there is no trend in the residuals, no outliers and in general, no changing variance across time. The blue line indicate the residual plot, red line indicate actual while green line indicate the fitted plot of the series analyzed. Fig 4 captured dependence in the series since there is no significant spikes from ACF plot of the residual and the plotted P-values for the Q-Statistic is above the 5% level of significance. The measure of efficient and parsimonious fit was evidenced from the AIC, SWC and log-likelihood. In addition, this model will provide a better fit if there exists no other model with fewer parameters, lower AIC and higher Log-likelihood.

The Jarque-Bera test of normality in figure 5 has a test statistic of 4.549, with P-value of 0.10285. This shows that normality is not rejected at 5% significance levels.

The forecast plot in fig 6 shows that the distribution of forecast tends to follow a downward trend with ±2 standard error limit. Therefore, there is high tendency for mortality rate due to malaria infection to reduce drastically between the years 2016-2018 on the long-run due to awareness and protection against mosquito bite.

CONCLUSION AND RECOMMENDATION

Conclusion

Having used neccesary and suitable method in line with the aim and objective of this study, there is no doubt that the main purpose of this project has been fully realized.

The research aim is to model and forecast monthly rate of mortality due to malaria and this was achieved through ARMA(1,1). Since our forecast tends to follow a downward trend with $\pm$ 2 standard error limit, we concludes that there is high tendency for Mortality rate due to Malaria infection to reduce drastically (between 2016- 2018) on the long run due to awareness and protection against mosquito bite.

RECOMMENDATIONS

Based on the findings in this research work, the following recommendations were made;

1. Medical practitioners should continue to improve on the existing facility which has suggested the decline in Malaria infection of future occurrence and hence use their facility to adequately combat the predicted rise in mortality rate due to malaria infection.
2. Seminars should be carried out to inform individuals on how to protect themselves from malaria infection, by using various W.H.O recommended precautions such as treated mosquito nets.
3. Finally, raise regular awareness on how to maintain steady decrease in deaths attributed to Malaria infections.

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